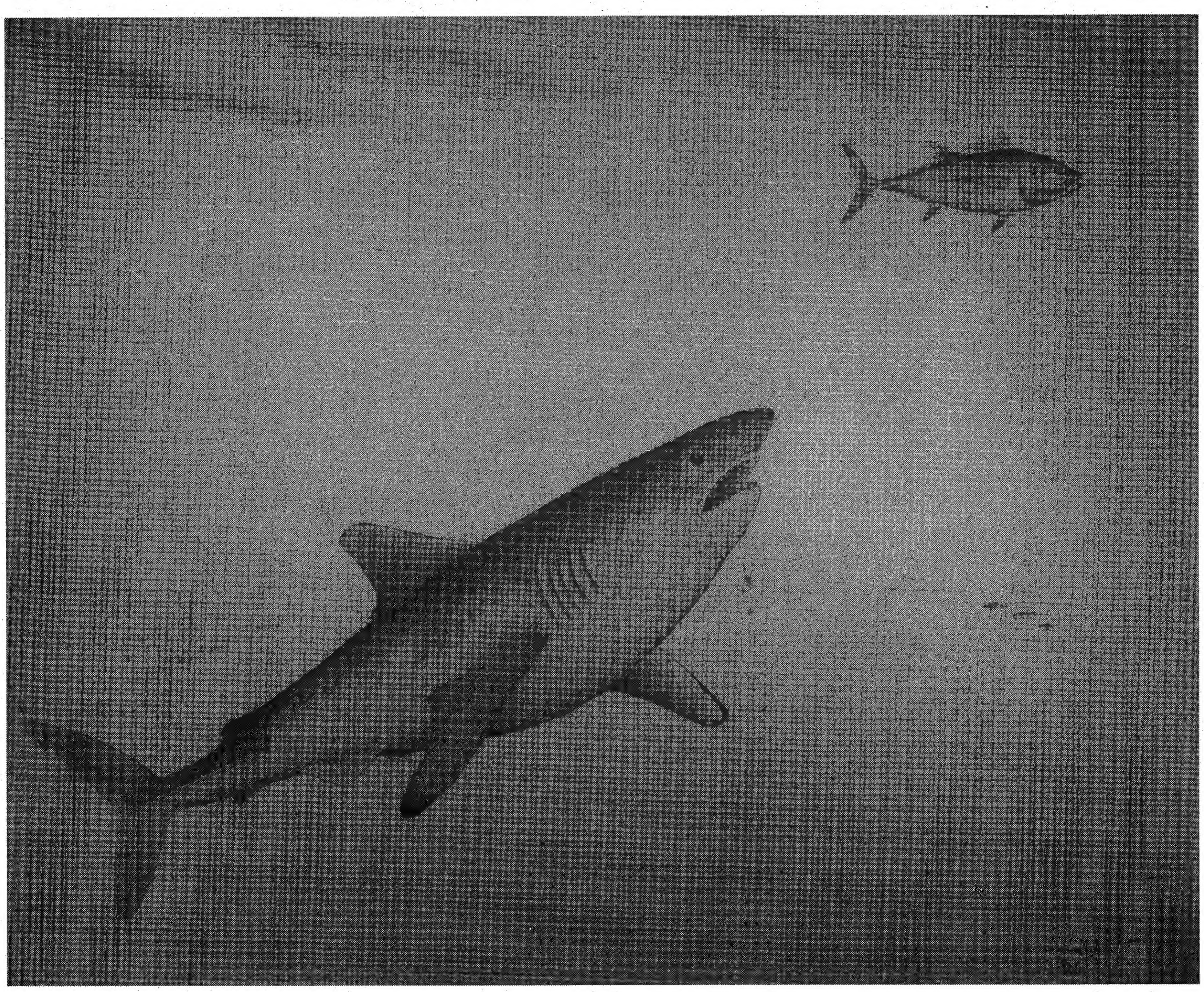
THE MOSASAUR



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COVER ART– "*Parotodus* Stalking Tuna" by David J. Kent.

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The Parlin Pit: Paleontology, Stratigraphy, and Depositional Environments at a Cretaceous Amber Site in New Jersey

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ABSTRACT — Early discoveries of New Jersey amber are reviewed, and the history of the Raritan Formation nomenclature and paleontology are discussed. The Raritan Formation is a valid stratigraphic unit, and we favor retaining the original definition and description, especially in its type outcrop area. Recent discoveries of insects, bird feathers and other fossil inclusions from the Parlin Pit (Linden Sand Company pit) are reviewed. The stratigraphy of channel deposits in the pit is described, and related to the amber-bearing beds. The depositional environment is interpreted as an estuarine channel, with accumulations of transported plant material (including amber) along a riverine tidal flat. Other estuarine deposits of this type could potentially produce amber.

Introduction

Recent discoveries at the Parlin amber pit near Sayreville, Middlesex County, N.J., have prompted this review of the history of fossil discoveries in the Raritan-Magothy beds of New Jersey with special reference to the history of work at this important site. This is warranted by the scientific significance of the site and the potential closing of the pit, with the possibility that the locality may not be available for general investigation for the indefinite future. We wish to document some of the stratigraphy of the pit as it was being excavated, and make some comment on the bearing this now dug-out section had on the depositional environment of the amber bearing beds as well as the source of much of the well-preserved plant material found at the pit.

Early Amber Discoveries in New Jersey

While the origins of the amber trade in Europe are lost in antiquity, the earliest mentions of amber discoveries in North America are a matter of scientific record. Hollick (1905) and then again Grimaldi (1996) have reported the earliest record of amber in America as dating back to 1821, when amber was reported from Cape Sable in Maryland, but an earlier record of amber in New Jersey exists. In 1816, Parker Cleveland wrote of some earlier discoveries in his textbook *Elementary Treatise on Mineralogy and Geology*:

"In New Jersey, on Crosswicks Creek, 4 miles from Trenton, it (amber) occurs in alluvial soil. The Amber is both yellowish and whitish, and occurs in grains or small masses, seldom exceeding an inch in length; it rests on lignite or carbonated wood, or even penetrates it, and is sometimes connected with pyrites. The stratum of lignite, which contains the Amber, rests on a coarse ferruginous sand and is covered by a soft bluish clay, embracing masses of pyrite. Above the clay is a bed of sand (Wister and Conrad). Amber also exists near Woodbury, in the same state, in large plates in a bed of marl; also at Camden, opposite Philadelphia, where a transparent specimen, almost white, and several inches in diameter has been found in a stratum of gravel."

By the parenthetical notation "Wistar and Conrad", Cleveland meant that he had obtained his information about amber finds on the Crosswick Creek from C. I. Wistar and Solomon White

Conrad. S. W. Conrad was a Quaker minister, a professor of botany at the University of Pennsylvania, and the father of Timothy Abbott Conrad, an early paleontologist who had a distinguished career with the New York Geological Survey and who described many Cretaceous fossils from the coastal plain of New Jersey.

Subsequently, amber finds have been noted from the Garden State from time to time. Berry (1911) for example notes in his monograph on Raritan Formation plants that John Finch read a paper before the Academy of Natural Sciences of Philadelphia in 1824 in which he noted the presence of amber in the New Jersey beds. The association of amber, lignite, and pyrite is part of the early definition of the Plastic Clay formation proposed by T. A. Conrad himself in 1832. This association has been noted in many subsequent descriptions of the Raritan-Magothy beds, which were first known as the Plastic Clays.

The other occurrences mentioned by Cleveland were possibly of different provenience. The Woodbury amber he described as occurring in large plates in marl was probably from the Hornerstown Formation, where this highly polymerized form is found today in glauconitc sand. The Camden occurrence may represent an anomalous find in the gravely Pennsauken Formation or it may be from one of the coarser beds of the Potomac-Raritan-Magothy deposits which also outcrop in this vicinity.

History and flora of the Raritan Formation

Cook, following Conrad, described the basal beds of the Cretaceous System in New Jersey as the Plastic Clays (1868). Use of the term Raritan Formation to describe these beds was proposed by Clark et al. in 1897. Kummel and Knapp first subdivided the Raritan into informal members in 1904, and in Weller (1907), the name Magothy Formation was introduced to describe the sequence of interbedded sands and lignitic clays overlying the Raritan in the Cretaceous coastal plain deposits. Spangler and Peterson (1950) correlated the lower part of the Raritan to the Early Cretaceous Potomac Group of Aptian-Albian age.

Meanwhile, paleobotanists were becoming interested in the fossil plants of the Raritan sequence. A clay report in 1878 by Cook and Smoch contained the first list of floral remains in the Raritan. In this report Leo Lesquereux, the eccentric Swiss-American paleobotanist, provided a list of 29 botanical entities. Later paleobotanists have, with good reason, generally disregarded this list. In fact, Lesquereux himself said of the fossils, "These specimens are few and poor..." (cited in Newberry, 1895, p. 29).

In *The Flora of the Amboy Clays,* Newberry (1895) described 156 fossil plant species from the Amboy Clay, a unit now thought to be a part of the Raritan Formation. The majority of his specimens came from the Cutter's Clay pit near Woodbridge, N.J. and probably represent the Woodbridge Clay Member of the Raritan Formation. Newberry was apparently somewhat lax about collecting detailed locality data. In fact, one locality, the Fish House Clay, which he placed in the Amboy Clay, is actually of Pleistocene age (Berry, 1911) and has produced teeth of *Equus* (Bogan et al., 1989). He considered that the Amboy Clay stretched from Cecil County, Maryland (where it overlies Potomac Group beds), along the east banks of the Delaware River near Camden, N.J., through the Raritan Bay area, and out onto Long Island. It is important that the majority of his collections came from what is now recognized as the middle member of the Raritan in its type area. He listed 8 species of ferns, 17 of conifers, 5 cycads, and 126 dicotyledonous angiosperms and correlated the Amboy Clay with the Dakota Group of Kansas, the Aachen Series of Germany, the Patoot and Atane beds of Greenland, and the Cretaceous plant-bearing beds of Bohemia. He also recognized the paleoenvironment as estuarine and cited the presence of the brackish mollusks, *Corbicula* and *Gnathodon* (Newberry, 1895, p. 22).

In 1911, Edward W. Berry published *The Flora of the Raritan*. Though the quality of Berry's work is doubted by many modern paleobotanists (e.g., Hickey and Doyle, 1977), this paper was the first review of the paleontology of the Raritan. The majority of Berry's material came from the Allen and Clark pit in South Amboy. He described 160 species of plants including a fungus, an alga, 9 ferns, 6 cycads, 2 gingkoales, 131 dicot angiosperms and roughly 20 conifers. Unfortunately, this is the most modern treatment of the Raritan macroflora that exists. It is in dire need of revision. Berry claimed that of 78 genera, only 32 were now extinct. This is clearly false and is an artifact of the practice, pervasive in early 20th century paleobotany, of assigning modern generic names to extinct forms. Berry's generic list includes certain believable names such as *Magnolia, Liriodendron, Celastrophyllum, Dewalquea, Auracarites* and unbelievable ones such as *Salix, Populus, Acer, Sequoia*, and *Thuja*. Based on a correlation similar to Newberry's, Berry dated the Raritan as Cenomanian (Upper Cretaceous).

In 1952, Dorf reviewed the Cretaceous paleobotany of the Atlantic Coastal Plain and used the plant fossils to refute Spangler and Peterson's (1950) claim that the lower part of the Raritan was equivalent in age to the Potomac Group of Maryland. He recognized that the Raritan was in part Cenomanian and in part Turonian in age, with the overlying Magothy assigned a Turonian-Coniacian age, largely on the basis of their contained fossil floras.

In 1943, Richards published the *Fauna of the Raritan*. He listed a number of estuarine and marine mollusks that have since yielded a mid-Cenomanian age (Sohl, personal communication in Wolfe and Pakiser, 1971). Stephenson (1954) reported additional invertebrate material from the Raritan Formation, pointing out that most of the invertebrates were marine forms from the upper part of the Woodbridge Clay Member. Vertebrate fossils found in the Raritan include sharks teeth, a plesiosaur bone, dinosaur footprints, and possibly a theropod bone (Baird, 1989; Case, 1989).

Doyle and Hickey (1977) summarized their approach to the study of early angiosperm evolution in the Cretaceous coastal plain deposits, and once again suggested that the Raritan was in its lowest part equivalent to the Potomac Group, based on their updated and integrated data on leaf and pollen fossils.

Validity of the Raritan Formation

Wolfe and Pakiser (1971) have redefined the Raritan Formation, removing the upper members to the overlying Magothy Formation. This was done largely on the basis of contained palynomorphs, which indicated that while the middle beds of the Raritan were Cenomanian, the upper units were Turonian and hence closer in age to the Magothy Formation. This implied an unconformity and hence a sequence boundary coinciding with the stage boundary. However, paleontological considerations are secondary when defining a lithostratigraphic unit, which is recognized on the basis of its physical characteristics rather than on its fossil content. Other well-known formations cross stage boundaries and even system boundaries (e.g. the Pierre Shale and the Hell Creek Formation of the Western Interior). Moreover, if the basal beds of the Raritan are actually correlative to the Lower Cretaceous Potomac Group, as suggested by some authors (Doyle and Hickey, 1977), and the upper beds are considered to be Magothy, is there any sense to maintaining the name Raritan? We feel that the original definition of the Raritan as a lithostratigraphic unit should stand, and hence we employ it here to describe the beds at the Parlin Pit. Certainly the Raritan Formation has stratigraphic utility as a mappable unit, and its economic importance as an aquifer has long been recognized. We prefer the position of Jordan (1979) who suggested retaining the use of the name Raritan Formation for the beds exposed in the type section area. Typical Magothy Formation beds consisting of interbedded sands and lignitic clays were exposed at Cliffwood Beach and Oschwald's pit, and are distinctly different from the Raritan Formation deposits.

Insects and other fossils in amber from New Jersey

In 1967, Wilson et al. described what were then the oldest known ants, two specimens preserved in amber found along the beach at Cliffwood, Monmouth County, N.J. The piece of amber was in a clay block; the Magothy Formation was exposed at Cliffwood Beach, so the specimens were inferred to be from the Magothy Formation. This exposure has since been covered with riprap by the Army Corps of Engineers. Wilson et al. named the ant specimens *Sphecomyrma freyi*, and determined that they were worker ants of a new subfamily, the Sphecomyrminae. These ants displayed several features that were more wasp-like in character.

Michener and Grimaldi (1988) reported the oldest known bee, again from New Jersey amber. This specimen, which they named *Trigona prisca*, was discovered in a collection of amber from Kinkora in Burlington County, N.J. This insect is remarkably advanced, sharing a number of pollen-gathering features with modern bees.

About 1991, excavations at the Parlin Pit reached a rich layer of amber-bearing lignite. It was at this point in time that private collectors, most notably John D'Orazio, began bringing the attention of others to the lignite beds at the bottom of the Linden Sand Products pit. Excavations of the lignite layers yielded large quantities of amber, and many pieces contained insects and other fossil arthropods. Studies of the fossil arthropods ensued; Gelhaus and Johnson (1996) named two new species of cranefly, and listed at least 30 families of insects from the amber found in the Parlin Pit. Preservation of some of these specimens is exquisite, revealing delicate structures such as bristles, antennae, compound eyes, and wing veination; in some cases the original iridescent sheen is retained on specimens of beetles.

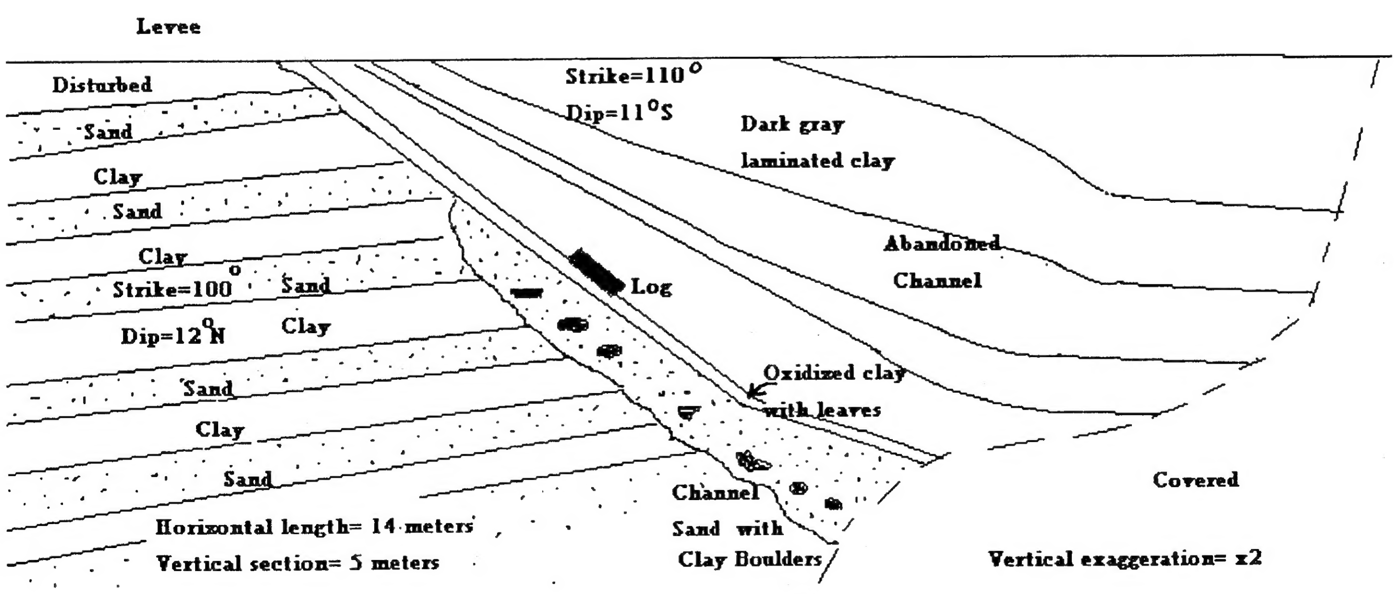
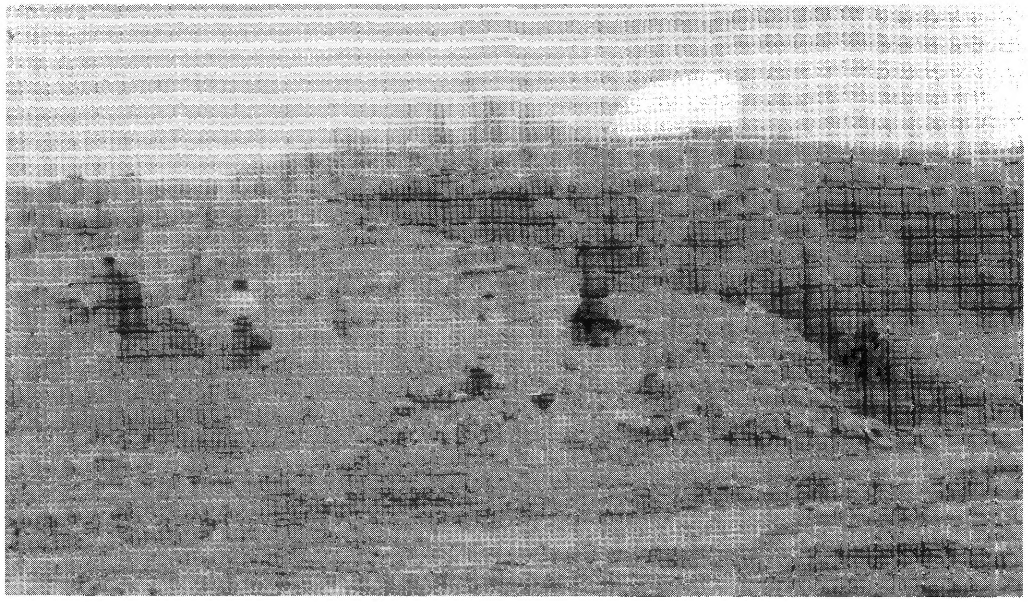


Figure 1. Stratigraphic section at Parlin Pit (Linden Sand Products) depicting levee-abandoned channel- oxbow complex exposed during April, 1985.

Figure 2. Channel plug (on right) cutting dipping levee deposits (on left side of picture). Parlin pit, April, 1985. Students for scale.



Other arthropods are found in the amber. A number of spider specimens are known from Parlin Pit, and a portion of spider web has been found preserved in the Cretaceous resin. Among the most unusual specimens from the Parlin Pit amber is a pseudoscorpion. This is a small stingless relative of the larger true scorpions. Today pseudoscorpions are widespread but often unnoticed because of their small size and cryptic habits; they often inhabit the nooks and crannies of tree bark, making them likely candidates for encapsulation in sap.

Even bugs can be bothered by parasites, and some of the specimens preserved in amber display ancient examples of parasitism. Specimens of midges with mites attached to them are found in the Parlin amber. Mites are tiny relative of ticks.

Among the most remarkable specimens in the New Jersey amber are two bird feathers from the Parlin Pit (Grimaldi and Case, 1995). These are the oldest known bird fossils from eastern North America.

Stratigraphy at the Parlin Pit

We began studies of the Parlin Pit stratigraphy in 1984-1985, as part of an exercise in teaching stratigraphy at the University of Pennsylvania. At that point in time we were primarily interested in interpretations of depositional environments, particularly with respect to a bed of plant fossils found in the pit. Preliminary results of this study were published in Gallagher and Johnson (1986). Subsequently, several more visits were made to the pit over the next ten years, as excavations proceeded and the rich amber bed at the base of the pit section was revealed. We wish to document that now-missing stratigraphy in light of the significance of the amber beds.

In October of 1984, preliminary reconnaissance in the Sayreville area of Middlesex County was undertaken by graduate students of the University of Pennsylvania as part of a regional geology symposium. We were specifically interested in discovering new exposures of the Raritan Formation that might yield plant fossils. At the Linden Sand Company pit in Parlin, N.J., we found an interesting exposure that revealed an upper layer of lignitic clay with marcasite nodules underlain by light brown silty fine sand intercalated with clay. Bedding surfaces of the intercalated clay-sand strata contained fragile fossil leaves and plant hash; preliminary determinations were that the leaves were dicotyledons of Cenomanian age.

As part of the spring semester course in Stratigraphy 206 in 1985, it was determined that we would make this exposure and its fosiliferous strata a class field exercise. Further excavation at the Linden Sand Products pit had exposed what looked to be infilled ox-bow lake or abandoned channel with adjacent levee deposits. We received permission from the owner, Mr. Joseph De Fino, to excavate and study the section. We quickly determined that the majority of the fossil leaves were occurring in a reddish brown clayey silt that underlay the gray clay. Common genera in this thin bed included the fern genus "*Asplenum*", the conifers *Araucarites, Elatides,* and cf. *Metasequoia*, and the early angiosperms *Protophyllum* and *Sapindopsis,* . There were also large quantities of unidentifiable plant material and lignitic logs at the base of the gray clay, just above the leaf-bearing unit.

Elsewhere in the pit, to the north some deeper excavations had uncovered in one small spot a lignitic layer containing lignitic logs, marcasite nodules, and amber associated with the lignite. This may have been the first glimpse of the amber bearing layer. Active bulldozing of this spot prevented closer prolonged investigation. Across the railroad tracks to the east, older exposures in back of the local municipal park provided weathered outcrops of Woodbridge Clay with many marcasite concretions and numerous lignitic logs, some of which were well-preserved enough to display distinct growth rings. To the south and across the railroad tracks at this time there were a series of cliffs with an extensive exposure of cross-bedded reddish orange sands; the foresets of these cross-beds contain lignitic lenses. One mile to the west of the Linden sand pit are the old Fisher-Sayre pits mentioned prominently in some of the old literature.

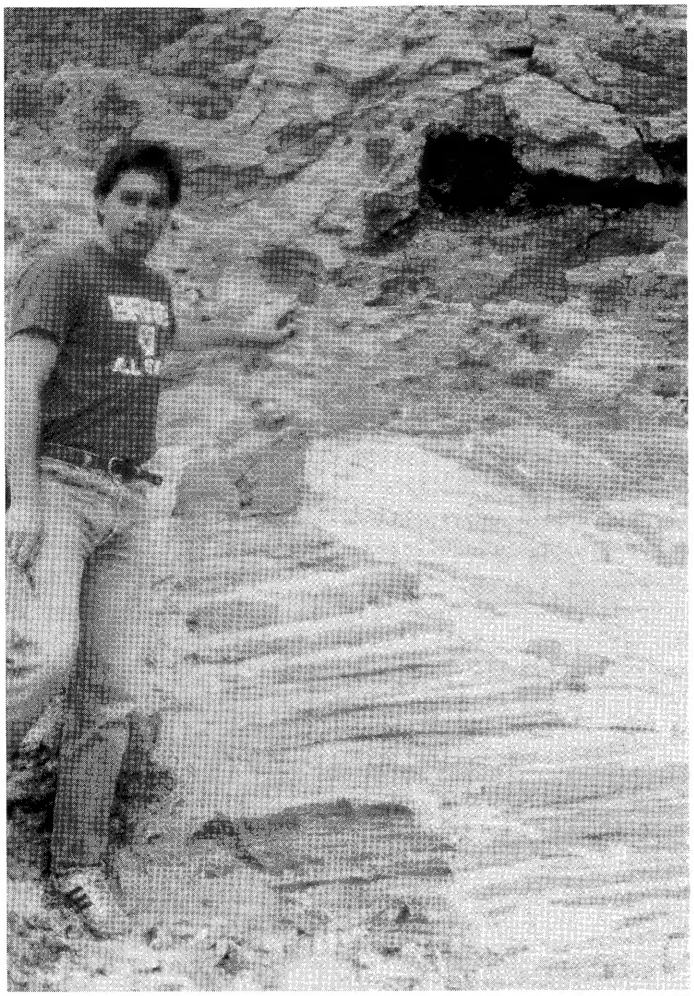


Figure 3. Close-up of channel sand at base of channel fill deposit cross-cutting fine-bedded dipping levee deposits; dark gray clay plug above.

Subsequent visits involved exposing the basal relationships of the fluvial depositional system, measuring and describing the section, and collecting more paleobotanical material. The north dipping levee sands and clays were abruptly cut by fine white channel sand dipping south; in the base of the channel sand above the levee deposits were several clay clasts obviously derived from the cut-bank of the levee. The lignitic dark gray clays above the channel sand dip to the south near their thin margin on the north, but they become essentially horizontal as they thicken over the channel center to the south. Uncovering their relationship to the channel sand, they are separated (gray clay above, white sand below) by the yellowish brown clayey silt unit that yields the fossil plants. The silty unit could be traced through other exposures to the east in the pit, where it also yielded fossil plants, including ferns, conifers, and platanoids.

A later visit to the Linden pit in May of 1985 came after more excavation of the cliff revealed the abandoned channel. At this point another smaller channel was visible just to the north of the main channel deposit; this smaller feature could represent a tributary or a meander of the same stream. The north-dipping interbedded sand and clay beds are typical of levee deposits, with sand units representing the maximum high energy flooding events and the clay beds indicative of waning phases of flood. In the south end of the exposure, there were thinly-bedded lignite and silty fine sand that presented a varved appearance; this may represent seasonal sedimentation in the center of the meander cut-off oxbow lake. Section measuring of the channel-levee complex was essentially completed at this time

One section was measured upward through the levee deposits; this revealed a 2.6 meter sequence of 30 alternating beds of fine sand and clay. A second section several meters in thickness was measured through the contact of the levee and abandoned channel; this showed the presence of a coarser quartz sand irregularly cross-cutting the regularly layered fine sand-clay alternating beds. This quartz sand unit contained clay blocks of the same lithology as the cross-cut laminated clay beds, oriented along the southsloping bottom of the sand unit; one such block measured 20 cm long by 7 cm high. These blocks are interpreted to be rip-up clasts derived by erosional events from the cross-cut units. Above this was a yellowish brown clayey silt which contained the majority of the fossil leaves. The superjacent beds were largely gray organic-rich clays; just above the leaf-bearing silt there were lignitic logs which followed the slope of the dipping silt layer. Finally, a third section 2.8 meters thick was measured near the thalweg of the channel; this was mostly brown and gray clay, with a medium-grained sand containing massive clay clasts at the base. A prominent lignitic marker bed followed the dip into the center of the channel where it leveled out with the other beds.

Subsequently, nearby outcrops were visited in November 1986 and the thin leaf-bearing silt layer was traced through other exposures; the silty layer was always between a quartz sand and a gray clay, as first observed at the Linden Sand pit. An additional observation made at this time was that many of the lignitic logs displayed *Teredo* type borings.

In the early 1990's, much of the section described above was removed as the pit was dug deeper and the property changed hands. At this point, the bottom of the pit was just above a lignitic layer that contained numerous amber pieces. Some of the amber contained fossil insects and other arthropods, including representatives of some thirty families of arthropods (Gelhaus and Johnson, 1996). Active excavations of this layer were undertaken by a number of collectors, and a great number and variety of fossils were found. The amber bearing strata is overlain by light gray sand and massive dark gray (N4) clay layers; the amber unit is actually divisible into two lignites, an upper thicker layer that yields many smaller pieces of amber, and a thinner lower lignite that contains fewer but larger amber pieces. These two layers are separated by a thin sand layer. The lignitic layers dip steeply to the southeast, and in plan the lignitic beds have an arcuate shape. The lignites are composed of comminuted plant matter, including individual conifer needles, compressed twigs, branching stems, leaf cuticle, some possible seeds, and much material that is only identifiable as lignite. The lignites may be described as a grayish black (N2) to black (N1) silty very lignitic clay. It is almost

matted in places, like a peat of finely interwoven twigs. Very thin interbeds of light gray medium well-sorted quartz sand were also observed in the lignites. Some of the amber pieces appear rounded, tubular, and/or worn; there are very weathered-looking pieces that have a rind, while other pieces are clear. Some pieces are entirely opaque, while others are zoned, with both clear and opaque sections in the same piece. Inclusions include pieces of plant material and vacuoles, besides insects and other arthropods. These deposits also have yielded charcoalified flowers (Crepet, 1992).

Interpretation

We interpret the upper section first measured at the Linden sand Products pit in 1985 as a meandering channel at the base, cross-cutting levee sands and clays. The levee sands and clays are non-rooted, flaser-bedded north-dipping beds representing cyclic deposition on a tidally influenced channel. These alternating sands and clays are truncated by a south dipping fine to medium grained light gray channel sand. The thin leaf-bearing unit above this is a transitional environment representing some sort of episodic deposition; the oxidized clayey silt was laid down when the channel was not completely cut off, and leaves may have been washed in during flood events. Seasonal flooding may have been the result of a Tethyan monsoonal seasonality; evidence for seasonality is contained in the channel cut-off deposits at the top, where varve-like bedding was observed in the clay plug fill of the oxbow lake depositional environment. In addition, the growth rings observed in the associated lignitic logs imply seasonality.

The amber-bearing lignites were located stratigraphically one to two meters below the visible base of the abandoned channel deposit. Their arcuate nature, the dip of the beds, the lack of rooting in the lignite, and the rounded and weathered looking appearance of the amber suggest to us that they were transported, perhaps in an estuarine channel to a strand line along a riverine tidal flat. Today North Sea and Baltic amber is collected along the beaches after weathering and transport; since amber floats this is a common way to find it (Poinar and Poinar, 1994). The comminuted lignite with small twigs, leaves, and conifer needles were washed up by the same fluvial processes concentrating the amber; concentrations of this sort are known from upper (proximal) estuaries in the Orinoco delta (Scheihing and Pfefferkorn, 1984). The evidence for an estuarine depositional environment is strong; many of the lignitic logs contain *Teredo* borings and today *Toredo* and its kin flourish in salinities of ten to twenty parts per thousand (Hoagland, 1983); if the water is too salty or too fresh, the shipworms will not reproduce successfully because of osmotic stress. Additionally, Richards (1943) reported that some of the marine invertebrates found in the Woodbridge Clay Member were estuarine species.

Putting all this together, we can say that the leaf-fossil assemblage and the lignitic amber-bearing beds are products of closely associated but different depositional environments. The leaf flora accumulated as the result of flooding events in a partially cut-off meandering channel, while the amber beds accumulated along an estuarine strand line as a result of transport downstream; the lignitic matrix is more corroded and less pristine than the leaves from the channel deposit.

Such associations should be kept in mind while prospecting other outcrops of this sort for amber or paleobotanical materials. While this site may soon be built on, and much of the stratigraphic associations are destroyed or obscured, it may serve as a model for future investigations.

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